I. INTRODUCTION

1. In February, 1960, the Minister of Agriculture, Fisheries and Food, together with the Minister for Science, the Secretary of State for Scotland, and the Minister of Health, appointed a Research Study Group on Toxic Chemicals used in Agriculture and Food Storage under the chairmanship of Dr. (now Sir Harold) Sanders, the Chief Scientific Adviser on Agriculture to the Ministry of Agriculture, Fisheries and Food, to study the need for further research into the effects of the use of toxic chemicals in agriculture and food storage.

2. The Study Group's report, which was published in September, 1961, did not reveal any serious gaps in research on toxic chemicals, but it did indicate some potential weaknesses and emphasized the need for keeping the problems continually under review. The Government accepted the conclusions of the report; subsequently the Research Councils and the Ministry of Agriculture, Fisheries and Food were authorised to make some additional staff appointments to enable certain surveys and research to be intensified and some new work to be started.

3. The Study Group expressed the hope that there would be periodic consultations between Research Councils to keep under review the research being done under the aegis of each, including that relating to the interactions between pesticide use and wild life. The Minister for Science asked the Agricultural Research Council to make the necessary arrangements on behalf of the four Research Councils. A Research Committee on Toxic Chemicals was therefore set up under the Chairmanship of Professor A. C. Frazer, a member of the Agricultural Research Council.

II. TERMS OF REFERENCE

4. The terms of reference of the Research Committee are:—

(i) to keep under review research done under the auspices of the Research Councils on the effects of toxic chemicals* used in agriculture and food storage; and to make recommendations for future research;

(ii) to report to the Agricultural Research Council and through it to the other Research Councils† and to the Minister for Science.

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* As defined in paragraph 11 of the Sanders Research Study Group Report: "... any pesticide, that is, insecticide, fungicide, herbicide, rodenticide or similar chemical, used in agriculture (including horticulture) and food storage."

† Medical Research Council, Department of Scientific and Industrial Research, and Nature Conservancy.

III. SCOPE OF THE PRESENT REVIEW

5. At our first meeting in March 1962, we examined the recommendations of the Sanders Research Study Group, reviewed the fields of research that might be apposite, and discussed the allocation of responsibility between the Research Councils.

6. At the request of the Minister for Science we prepared an interim report in November 1962 which summarised new research started by the four Research Councils and the Ministry of Agriculture, Fisheries and Food to implement the recommendations of the Sanders Research Study Group during the year since the publication of its report. Reference was made to this report by the Minister in the Debate in the House of Lords on 20th March, 1963.

7. It was evident that detailed and expert reviews were needed in certain fields, and accordingly we formed a number of working parties, the members of which are given in Appendix 1. These working parties did not confine their attention to research under the auspices of the Research Councils because to do so might have led to their recommending additional work that would duplicate research already being done by other organizations.

8. The use of the words "toxic chemicals" might be taken to imply that substances so named are toxic to all forms of life but in fact most of the substances used to control pests in agriculture are to some extent selectively toxic. We have therefore preferred to use the word "pesticides" as this implies, correctly, that the substances have been introduced because they display, at least to some extent, a selectively toxic action against one or more pests. The primary effects of their use should therefore be beneficial to agricultural production and food storage. However, there may be secondary effects that are not always beneficial, and it is these that we have mainly considered.

9. The secondary effects that have attracted most general attention are those due to non-specificity of pesticides; some pesticides are toxic to a wide range of animals or plants and none is effective against only a single species. Consequently when a pesticide is applied over an area, there may be risks to species other than those aimed at. The first problem was how to find out the nature and extent of such risks. Accordingly we assembled a working party to advise us on ecological studies.

10. We examined also the possibilities of reducing the risks to wild animals and plants, however slight they might be. One way of doing this is to use pesticides less or to use less persistent ones. It is now well established that pest control is essential to British agriculture, but a more critical assessment of the need for and value of pesticides might lead to some decrease in their use. Other methods might be introduced if they were as effective and economically feasible. We therefore asked two working parties to report on the research being done on possible methods of pest control to substitute for the use of pesticides.

11. Although there are some other methods available that might be used instead of chemicals, their introduction is likely to lead to only a small reduction in the use of pesticides. Even with a greatly increased research effort in this field, it is evident that the continued use of pesticides on a wide scale will still be necessary. Accordingly, we asked another working party to report to us on the

biochemical and toxicological researches that are needed for the evaluation, reduction, and control of any risks that may arise from the continued use of pesticides. Finally, since the identification and measurement of pesticide residues in mammals, birds, fishes, insects, plants, soil, water, food materials, human tissues, or elsewhere, are essential in both research studies and control investigations, we asked a working party to consider the chemical and physical aspects of these problems, with special reference to analytical methods.

IV. ECOLOGICAL STUDIES IN RELATION TO THE USE OF PESTICIDES

12. Ecology is the study of animals and plants in their natural habitats. It is often necessary to study organisms in a controlled environment in the laboratory, and conclusions reached in this way are valuable; but they are only general guides to what may happen in complex and varying natural surroundings.

13. The most important use of the countryside is the production of food for man and it is inevitable that other animals and plants will be affected. Some species increase greatly and become pests, while others suffer local elimination due to, for example, the change from original forest to ploughed land, quite apart from effects of chemicals. The spread of towns has also a big effect, increasing populations of some species and reducing others. The problem is how to assist rather than hinder food production, bearing in mind the widespread desire to maintain the diversity of wild life. Apart from a few special cases, such as certain birds, in which the surviving individuals of an interesting species are very few in number, the focus of concern is the *population* and not an individual here and there. There is, however, little numerical information about animal populations and their fluctuations, and consequently there is usually no sound basis for deciding whether a species is tending to increase or to decrease. This numerical basis is not easy to secure, partly because most species vary greatly in numbers from year to year owing to the effects of weather conditions, so that perhaps a decade of research would be necessary before one could recognise and evaluate effects on populations caused by changes in agricultural methods as distinct from natural fluctuations of those populations. Even the process of enumeration is itself complex, laborious and sometimes uncertain, and has not generally attracted research workers.

14. It might be supposed that laboratory work on the toxicology of the chemical substances used and analytical investigation of animals, plants, water, soil, or other materials, might suffice, but, as will be more fully discussed later in this report, these studies have only a limited value in enabling us to understand fully the effects of pesticides on animal and plant life. This inadequacy has diverse causes: for example, the variation in susceptibility of the many different species that may be involved and even of the different stages of development in the life of a single species; the dynamic nature of the ecological situation and the impossibility of reproducing this under laboratory conditions; and the alterations that may occur to the chemical agent itself as a result of exposure to natural conditions. We consider that there is an urgent need for quantitative ecological studies of whole populations, to record the present state of affairs and to provide a basis for the study of changes due to environmental factors, such as pesticides.

15. To pass to particular examples, we suggest that each River Board might usefully obtain the services of at least one properly qualified biologist to follow the faunal and floral changes in inland waters from year to year, as is done by the Trent River Board. Such changes might, moreover, be sensitive indicators of changing conditions on surrounding land.

16. Again, much census work is being done on aerial insects, but most of it does not aim to provide all the information required for understanding natural fluctuations in populations and is therefore not suitable for assessing the effects of new factors, such as pesticides. Standardization of census work and its extension, to measure diversity of populations and to facilitate analysis for identification of key factors affecting numbers, would be of great value to research on effects of pesticides.

17. A somewhat different approach is possible with animals living in the soil, because they move about less than those above ground and because certain pesticides persist and may accumulate in soil. It is therefore reasonable to study changes in populations of neighbouring plots that are untreated or treated with chemicals. A favourable situation for such studies would be permanent grassland, but the most relevant to agriculture may be land used for a normal rotation of crops. More extended studies are required of the inter-relations of organisms in the soil and of the effects of pesticides on these inter-relations. More work should be done in Britain on the possible accumulation of pesticide residues in soil animals.

18. Again, for birds and mammals the greatest need is for further population studies of single species and of those animals that depend on them, over a period of years, with measurements of birth rates and death rates. It is only after measuring fluctuations in numbers that further changes due to chemicals may be detected and assessed. With animals as sparse and mobile as most wild birds, significant trials of the effects of pesticides on populations cannot be done without proper control of the use of considerable areas of agricultural land; the feasibility and value of such trials should be examined.

19. Not only do the numbers of animals at risk fluctuate widely from year to year, but so also do the kinds and amounts of pesticides used. The situation cannot be satisfactorily studied unless both quantities are known. Quantitative information on pesticides actually used should be obtained and made available to research workers.

20. We have listed in Appendix 2A the institutions in which research on or related to ecological and population studies is in progress.

V. SUBSTITUTES FOR CONTROL OF PESTS BY PESTICIDES ALONE

CULTURAL CONTROL

21. Cultural control is the use or modification of normal cultural practices such as cultivations, crop rotation, date of sowing, choice of variety, spacing and hygiene, so as to minimize the damage done by pests and diseases. It is in fact, a deeply ingrained part of agriculture, sometimes the only known way or

the most important way of controlling a pest. When considering how a particular pest is to be controlled, knowledge of the ecology of the crop and its pests should be sought and the economic possibilities of using existing methods of cultural control and of devising new ones should always be examined, especially as cultural methods change.

RESISTANT VARIETIES OF CROP PLANTS

22. Differences in the capacity of varieties of certain cultivated plant species to withstand attacks by pests and diseases have been recognised and exploited over a considerable period of time. Indeed, even within one variety of a crop it is often possible to find some plants that are not attacked by a particular pathogen and this is due to some extent to a greater heritable resistance to attack in these plants. Such resistant individuals can be selected and used to breed a resistant variety.

23. The methods used in breeding for resistance are similar in principle to those used for other characters; in particular there must be adequate genetic variation from which to select in the same or related species and it must be possible to manipulate resistance as an independent character. Normally the breeding method used is to hybridize selected parents to produce new combinations of characters. The alternative to hybridization is the exploitation of mutations, whether occurring naturally or induced artificially. So far this method has met with limited success, although it may have a special application for certain groups of crops such as perennials (e.g. fruit trees) or crops that are vegetatively propagated.

24. Resistance to a single pathogen is seldom the only requirement—or even the principal one—of the grower, who must be most concerned with the amount of crop yielded by a variety and with its quality. In breeding for resistance, therefore, the plant breeder has to try to combine the primary inherited characters of high yield and high quality with the secondary characters of resistance to important pests and diseases. The breeder's work is further complicated by the fact that the pathogen, as well as the host, is likely to be variable, and the existence of several races of a pathogen or the appearance of new ones has in some instances confounded breeding programmes which have been in progress for many years; in others there has had to be a continuing programme of production of new varieties to deal adequately with variations in the pathogen. The most outstanding example of this phenomenon has been black stem rust of wheat (*Puccinia graminis*). The breeding of resistant varieties for the control of this disease has been going on in North America for more than 50 years and, despite the emergence of many new races of the pathogen, the plant breeders have usually managed to provide the grower with varieties resistant to current races of the disease.

25. More effort has been devoted to breeding for resistance to fungal and viral diseases than to insects and other pests. This has been stimulated mainly by the need to control diseases for which there is no adequate chemical control but also by the fact that resistant breeding material is more generally available. Similarly, more work has been done on annual crops than perennial because of the long-term nature of breeding in perennial crops. Two or three generations

of some annual crops may be bred in one year under experimental conditions, and this has proved to be important in the successful breeding of cereals for resistance to diseases. From the grower's point of view, the most economic method of pest and disease control is to use resistant varieties, but where an existing chemical method of control is economic and without significant toxic hazard it would not be prudent to pursue a long-term breeding programme which would be expensive and might be unrewarding.

26. One of the notable successes of breeding for resistance in this country concerns wart disease of potatoes (*Synchytrium endobioticum*). Immunity to this disease has been a requirement of all new potato varieties for the past 40 years, and the single source of resistance from which this was established has remained remarkably stable. With another fungus disease, late blight (*Phytophthora infestans*), on the other hand, although resistance genes in wild potatoes from Mexico were introduced into the breeding programme more than 40 years ago, they have not proved adequate against the genetic variability of the fungus, and the most that can be hoped for from the breeding programme is some degree of field resistance to the disease.

27. Relatively little has been done to exploit breeding for the control of insect pests in agricultural crops. Despite a prolonged search for resistance to frit fly (*Oscinella frit*), sometimes a serious pest of oats, no source of genetic resistance of sufficiently high degree has yet been isolated. There has been some success, however, in breeding for resistance to eelworm pests, such as potato root eelworm (*Heterodera rostochiensis*) which cannot readily or economically be controlled by chemicals. Among horticultural crops, resistance to gall mite (*Phytoptus ribis*)—the vector of reversion virus in blackcurrants—has been successfully transferred from gooseberries to blackcurrants, and the integration into commercially acceptable varieties of raspberries of resistance to four races of an aphid vector (*Amphorophora rubi*) of virus disease is now well advanced.

28. From our review of research in progress on breeding for resistance, we consider that more attention might be given to the possibility of breeding for resistance to insect pests in crops where no satisfactory control is known or where the present chemical methods are objectionable. An example is wheat bulb fly (*Leptohylemyia coarctata*) for which the most common method of control at present is to use organo-chlorine insecticides. No report has yet been made of sources of resistance to this pest, although field observations have indicated that there is a possibility of selecting resistant types. Similarly, differences in aphid attack on sugar beet and kale merit further study by the plant breeders in collaboration with specialists in the study of aphid behaviour.

29. We have listed in Appendix 2B institutions concerned with research on breeding plants for resistance to pests and diseases.

BIOLOGICAL CONTROL AND INTEGRATED CONTROL

30. Biological control is here intended to mean the use by man of predators, parasites, and diseases of pests, to reduce pest damage. It is important to realise, however, that in nature undisturbed by man, most species suffer considerable mortality from these *natural enemies*, which often limit their numbers.

When man intervenes by ploughing, planting, weeding, and cropping, some species are adversely affected, while others become numerous as pests, but often the natural enemies of pests continue to have considerable restraining effects. Such effects are valuable and should be interfered with as little as possible.

31. Conditions in such perennial crops as forests and orchards commonly allow insects to reach a rough equilibrium with their natural enemies, often at low pest density. It is then particularly valuable to make the most of these natural enemies and it may be undesirable for the equilibrium to be disturbed by the use of broad-spectrum and persistent insecticides, which has sometimes been observed to rebound to man's disadvantage.

32. Pests of annual crops mostly come from outside and often establish themselves speedily, causing economic losses before their natural enemies have had time to overhaul and control them. Chemical pesticides are thus necessary, especially if only a low level of infestation can be tolerated. When a moderate infestation can be tolerated, natural enemies may adequately limit pest numbers; if they do not, the man-managed counterpart, *biological control*, may be useful.

33. Our review revealed that, while a modest amount of research is being done in Britain on insect parasites and predators of insects (Appendix 2C), knowledge of the biology and ecology of pests and their natural enemies is inadequate. We are agreed that more resources should be devoted to increasing knowledge of the complex of crop, pest, and natural enemy. It is improbable—though not impossible—that any indigenous pest in Britain could be biologically controlled by introducing insects from abroad. On the other hand, it is likely that greater value could be obtained from indigenous natural enemies, once they are understood, either directly or by adjusting the kinds and the timing of chemical measures so as to minimize damage to these natural enemies.

34. Integrated control of a pest is the co-ordination of all known cultural, biological, ecological, and chemical methods in such a way as to obtain the maximum total benefit and especially to minimize harmful side-effects that may result from exclusive use of chemical pesticides. Before such integration is possible, much information must be collected about the complex of crop, pest, natural enemies, and insecticides.

35. In control programmes, it is of fundamental importance to know the level of pest population that is worth controlling and the damage to be anticipated from an infestation.

36. Organized, comprehensive studies, such as have been done already on orchard pests, should be started on certain other important pests, such as aphids. Research efforts should be planned to cover all aspects of the biology and ecology of the pest and of its natural enemies and all other factors, such as crop variety and weather, which control its numbers. Because of the enormous amount of work involved, choice should fall on those pests for which there is promise that practical results will be achieved and for which the present control measures are objectionable. The results will possibly indicate measures to increase control by natural enemies and certainly how to use insecticides so that harm to natural controlling factors is minimized.

37. Throughout the field of ecology and biology, accurate identification of the species involved (taxonomy) is of crucial importance, and this must often be followed by ecological studies of living biotypes (biosystematics). More taxonomists will be required if bionomic research is to be increased.

Birds as Predators

38. The part played by birds in pest control is uncertain, but may be seasonally and locally important: this needs quantitative investigation.

Diseases of Insects

39. The study of pathogens in insects—viruses, protozoa, bacteria, fungi, and nematodes—has been neglected in Britain compared with other countries such as Canada, Czechoslavakia, France, Germany, U.S.A., and U.S.S.R., where special laboratories for insect pathology have made some progress towards the use of these agents in pest control (Appendix 2C). If an insect pathology laboratory were to be established, it should initially contain two or three specialists on bacteria and viruses and should concern itself first with increasing the stock of fundamental knowledge and with exploratory work, rather than with immediate *ad hoc* trials. Such a laboratory might eventually be expanded to deal with fungi, protozoa, nematodes, and insects parasitic on insects.

40. It is not suggested that biological control of insects could take the place of chemical control, but the method, when successful, has the advantage of greater selectivity and of reducing the need to apply chemicals. The use of pathogens to control mammalian and avian pests, on the other hand, would seem to be unacceptable to the British public.

OTHER METHODS OF CONTROL

Sterilization by Chemicals and by Irradiation

41. Chemicals are available that reduce or stop reproduction without killing and these can be fed to pests, especially bird pests, in baits. The difficulty is to ensure that only the species to be controlled take the bait, and further fundamental work is required on food selection.

42. Laboratory-bred insects can be sterilized by chemicals or by irradiation and then released in large numbers to swamp the wild population. Conditions for so eradicating a pest species occur only infrequently; so far no species in suitable conditions has been found in Britain.

43. In British agriculture, sterilization of insects by poisoned bait may have limited application against some pests in plantation crops, glasshouses, and mushroom houses, where comparatively self-contained pest populations occur, not much affected by immigration; but fundamental work needs to be done on chemosterilants and on the hazards involved in their use.

Attractants

44. There has been a revival of interest in highly specific attractants for insects (accompanied by traps, chemical sterilants, or poisoned baits) and there have been promising developments, mostly in the U.S.A. Attractants, particularly sex attractants, should be studied for pest species in Britain that offer promise of control by such methods.

Repellents

45. The empirical search for repellents for the protection of crops against insects is likely to be unrewarding, as it has been against vertebrates.

Rejectants

46. Anti-feeding compounds against insects, on the other hand, offer more promise, especially if acting systemically, but again the empirical approach has been unrewarding. Fundamental work must be done on factors governing the feeding responses of pest insects and on the plant constituents responsible.

Bird Scaring

47. Work on acoustic scaring of birds is being done under the auspices of the Infestation Control Laboratory, M.A.F.F., and the Ministry of Aviation; on an experimental scale it shows promise, but it is difficult to apply in practice.

VI. BIOCHEMICAL AND TOXICOLOGICAL STUDIES

48. Biochemical and toxicological research on pesticides deals with their absorption and distribution in living organisms, their metabolism and the changes that occur in them, the effects they may produce, and their elimination, sometimes in changed form. For few pesticides is the full story yet known and a great deal more work is required, but the results of researches of these kinds are already playing an increasing part in the development of safer and more selective pesticides, and more effective antagonists and synergists. For example, the insecticide dieldrin is readily absorbed through the skin of both insects and mammals and is not rapidly detoxicated enzymatically, so that there is a tendency for it to accumulate, if exposure continues. Again, some of the organophosphorus insecticides are detoxicated more rapidly in mammals than in insects and this makes them safer to use.

49. Laboratory work of these kinds is not enough, but needs to be linked to knowledge of the ecology of the plants and animals exposed to pesticides, because lethal and effective doses vary under different conditions in the various species. Moreover, two compounds that are equally toxic to a pest species may differ greatly in their toxicity to other species, which may be present in some situations and absent in others. Thus both laboratory researches and field work are necessary to the choice of a pesticide.

50. Unfortunately the situation is not static. After a pesticide has come into use, strains of the pest may emerge that are resistant to it. Increasing the dose tends to lead to difficulties and changing to a different insecticide may do so too. In any case these solutions are likely to be effective for only a limited time before resistance again develops. In some cases resistance can be overcome or reduced by the addition of a synergist to the pesticide and an understanding of the metabolism of a pesticide may help in the selection of a synergist.

51. Little toxicological work is in progress on the effects of pesticides on wild life. Domestic animals and semi-domestic game birds are more easily

studied than wild creatures. We consider that further research is needed to determine the toxicity of pesticides to birds that can be handled in captivity, such as domestic poultry and pigeons, so that the toxicological significance of pesticide residues found in body tissues can be assessed. Such information, which would include observations on egg production, egg hatchability, and the survival of chicks, should give initial and general indications of the risks to which populations of wild birds may be exposed.

52. There have been occasional cases of human poisoning by pesticides. They have almost always been due to faulty handling of the pesticide or its container. Suggestions that there are more widespread effects have not been substantiated. From the research point of view it is important that any suspected case of poisoning by pesticides should be investigated as thoroughly as possible. Studies are also needed to extend the range of diagnostic methods, so that unequivocal evidence of exposure or poisoning can be obtained. Research is also needed into the diagnosis, prevention and treatment of toxic effects, although such measures will be required only for occasional individuals accidentally grossly exposed. As in the case of other creatures, it is important to know whether the presence of traces of pesticides in body fat or other tissues has any toxicological significance.

53. The detailed study of the biochemistry and toxicology of pesticides is not only of potential value to agriculture, but may also provide information of much wider application and significance, so that support for basic research in these fields may be justified on general scientific grounds. The main limiting factor is the availability of suitably trained biochemists, pharmacologists, toxicologists, and animal pathologists, and it may be desirable to take steps to improve the supply of scientific man power in these fields.

54. Assessment of the hazards that may attend the use of a pesticide can generally be considered in two phases. The first phase requires information sufficient to indicate the conditions under which the substance can be safely applied in experimental work to evaluate its usefulness in agricultural practice. Data on absorption through the skin or on ingestion or inhalation are essential when considering the need for protective clothing of operators and for the recommendation and enforcement of suitable precautions. If it is found to be of value agriculturally, it may be desirable to release it for commercial use. This may involve exposure of members of the public to the substance; so further information on long-term effects may then be necessary. Methodological research is still required on detection of long-term effects.

55. Under the Notification Scheme* no new compounds are brought into commercial use until sufficient information has been provided to enable an assessment of any potential hazard to be made by an independent expert panel.

56. From the aspect of safety, the most important investigations are those that relate either to substances to which the general population or large numbers of people may be exposed or to those to which special groups might be dangerously exposed. To identify these substances, it is necessary to know the

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* The Notification of Pesticides Scheme agreed between Government and Industry, 1957 (revised 1960), administered by the Ministry of Agriculture, Fisheries and Food.

nature, quantities, and methods of application of pesticides actually used throughout the country. If possible, this information should be obtained and made known to those who may have to decide on research priorities and to certain groups of research workers.

57. We have listed in Appendix 2D some of the institutions where biochemical and toxicological studies on pesticides are in progress.

VII. CHEMICAL AND PHYSICAL ASPECTS

ANALYTICAL METHODS

58. The difficulties of analysis for pesticide residues arise from the need to determine minute quantities ranging from parts per million to parts per thousand million of plant or animal material. This range of concentration is set by the levels of residues that are found in practice and by the tolerable levels. The determination of such minute quantities has become possible only because of the tremendous advances made in analytical chemistry during the last decade. Instrumental methods are now very sensitive, but some of them are too costly for the smaller laboratories of some Public Analysts concerned with food and drug inspection. A special effort should be made to develop for this purpose exact but less expensive systems of qualitative and quantitative analysis, of which paper chromatography is a simple illustration.

59. The removal, from a sample, of materials that interfere with the final measurement of analysis (the clean-up stage) affects the sensitivity of a method and has presented great difficulty in residue analysis. Methods must be both sensitive and specific. Confirmation of the identity of a pesticide normally requires the use of at least two independent physical methods. Gas chromatography may be used to determine very low levels of certain pesticides, but no other physical method exists which can yield confirmatory evidence at these levels.

60. There are analytical facilities at all institutes concerned with research on pesticides; these are listed in Appendix 2E. They are widely used in such studies as assessment of application efficiency and persistence. The methods used include those submitted or published by the manufacturers of pesticides and used by them to obtain information to satisfy the authorities in those countries, including Britain, where the pesticides have been introduced. Modifications to these methods are often necessary for particular purposes and are devised at most institutes; in addition a few laboratories, notably the Government Chemist's, are working on the general development of methods for the detection and measurement of pesticide residues. Bioassay methods are of value for detecting the presence of pesticides in foods; and there is a need for bioassay in field trials on the biological efficiency of different types of spray deposit. Satisfactory field-testing methods for low concentrations of toxic vapours are essential for the safe use of fumigants and simpler, more accurate, methods should be developed. International collaboration and exchange of information on residue analysis is extensively practised and should be encouraged as much as possible.

61. Analysts would be greatly helped by a better knowledge of the products formed by metabolic or other alteration of the pesticide applied; little work has been done in this field. The metabolic and weathering decomposition products of many of the organo-phosphorus insecticides, for example, are not sufficiently well defined.

62. In order to make full use of the precise analytical methods now available, it is essential that there should be a central organization to supply analytical standards and information about the chemical and physical properties of pesticides and methods for their analysis.

SURVEYS

63. Surveys of pesticide residues in both home-produced and imported foodstuffs have been initiated by the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage. Other surveys of residues in human tissues, growing crops, soils and wild life are also in progress; these are listed in Appendix 2F. These surveys are, in the main, of a preliminary nature, being based on spot sampling rather than on a statistically designed sampling system; no detailed results are yet available.

64. It has been suggested that there is a need for a comprehensive monitoring programme comparable with that already operating for the monitoring of radioactive fall-out. Such a programme was recommended in the Report on the Use of Pesticides by President Kennedy's Science Advisory Committee. We are unable to say whether such a service would be of value in this country until the results of the preliminary surveys are known and until the toxicological significance of residues so found has been considered. If it is decided that there is a need for the regular monitoring of pesticide residues, the Research Councils should be consulted on the design of the surveys and on the statistical analysis of the results, although they will not necessarily be concerned with the operation of the monitoring programme itself.

65. Apart from the investigations being carried out by agricultural research scientists, the only other specialist group examining retail food products are the Public Analysts. An approach might be made by the Government Chemist to the Association of Public Analysts to obtain further information.

66. There is evidence that fish accumulate some insecticides and that fish-eating birds are acquiring residues by this route: some further examination of the contamination of water would seem to be desirable and this would require the collaboration of the Nature Conservancy and the Water Pollution Research Laboratory with River Boards and with government departments concerned with water resources.

NEW PESTICIDES

67. The development of new pesticides must remain largely in the hands of industrial laboratories, which are clearly most suitable for such work. There is a continual need for new pesticides to combat the development of resistance to those already in use. Moreover, combined chemical and biological research should be directed to the development of more selective and hence less generally

toxic pesticides. However, a pesticide that is ideal from a safety point of view might be effective against only a single pest species; such a pesticide, because of its limited use, would be sold in smaller quantities than one with a wider range of action. Thus the highly selective pesticide may not be commercially attractive. Economic aspects of the development of highly selective pesticides require examination; further support may be worthy of consideration for basic work outside industry on chemical structure in relation to biological effectiveness, particularly in order to develop more selective pesticides.

APPLICATION OF PESTICIDES

68. Problems of formulation and application merit research at governmental and academic establishments, and liaison with industry in these fields should be increased. These topics require the collaboration of chemists, biologists, engineers, and others on such problems as spray-machine improvement, improvement in formulation and in the efficiency of application to agricultural targets. Such research could well lead to the use of smaller amounts of pesticides to control certain pests and diseases, and this in turn could reduce toxic residues and any hazards likely to arise therefrom. Some work on formulation and application is being done at a number of research institutes, and engineering problems of machine design are being investigated at the National Institute of Agricultural Engineering and at Long Ashton Research Station; this work should be intensified.

VIII. DISCUSSION

69. The main research problems on pesticides may be grouped under eight heads.

A. Assessment of hazards arising from the use of pesticides.
B. Development of methods of pest control.
C. Development of new pesticides.
D. Control of potential hazards.
E. Co-ordination of effort.
F. Manpower.
G. Further Research Needs.
H. Priorities.

A. ASSESSMENT OF HAZARDS ARISING FROM THE USE OF PESTICIDES

70. Existing knowledge and the methods at present available for the study of the possible effects of pesticides on human health, on the welfare of domestic animals, and on wild life, are not adequate for the full assessment of the hazards involved. The demonstration of small amounts of pesticide residues in the tissues of man, domestic animals, or wild creatures, is of little value until more information is available on their toxicological significance; more toxicological studies are therefore urgently required. Ecological work involving population studies on chosen species is necessary before effects of pesticides on wild life can be measured.

B. DEVELOPMENT OF METHODS OF PEST CONTROL

71. A wide variety of methods is desirable for the effective control of pests. More research should therefore be aimed at methods of pest control that are not dependent solely on pesticides. There appears to be scope for development of plant breeding for resistance to insect pests, but the chances of success in this field should not be over-estimated. More research on biological methods of pest control is needed in this country.

72. Although there is a need for more research on breeding for resistance and on certain forms of biological control, it should be stressed that the best results may be expected from a close integration of these methods with the use of pesticides. Research is needed on the most effective ways of applying each method or combination of methods.

C. DEVELOPMENT OF NEW PESTICIDES

73. Perhaps the most important potential limitation on the use of pesticides is the emergence of resistant strains of pests. Such developments can be delayed by more intelligent use of existing methods of control, but continual production of new pesticides will be necessary. Resistance is particularly serious when it necessitates the abandonment of a relatively safe pesticide. Industrial laboratories are rightly the main centres in which new pesticides are produced. There is a continuing need for new pesticides that are effective against resistant pests.

74. There is, however, another aspect to be considered—namely, the development of more selective pesticides—but there may be limiting economic factors. It is therefore desirable to encourage research, outside industry, on the relationships between chemical structure and biological action, and on modes of action, mechanisms of resistance, synergists, antagonists, and other aspects of the biochemistry and pharmacology of pesticides which may lead to the development of safer and more selective pesticides of more limited persistence.

D. CONTROL OF POTENTIAL HAZARDS

75. More satisfactory methods of assessment of the effects of pesticides would contribute greatly to satisfactory control of any hazards involved. Pharmacological and toxicological research provides the information upon which effective control measures must be based. Every new pesticide must, therefore, be adequately studied from this point of view. Regulation may also depend upon analytical information, so that the development of analytical methods of appropriate sensitivity is important.

76. We are not concerned with the administrative control of pesticides, which is fully dealt with by other authorities. There is, however, close liaison between research workers and the controlling authorities and this liaison should be encouraged. If any priority is to be given to those pesticides that are most widely used or that may present special hazards to relatively small groups, it is necessary to have information about the nature, methods of application, and distribution, of the various pesticides actually being used throughout the country each year. This information may also be needed for some epidemiological and ecological studies.

E. CO-ORDINATION OF EFFORT

77. Several working parties emphasized the need to bring together research workers in certain fields:—

(a) to discuss standardization and extension of census work to make it more useful for studies on pesticides;

(b) to establish more effective integration of ecological knowledge, biological methods of control, and the use of pesticides;

(c) to correlate work in the analytical field, including that done by Public Analysts.

F. MANPOWER

78. In any research field there is always room for further development or more intensive study. One of the main limiting factors is the availability of suitable people to do the work. Accommodation, equipment, or special facilities for research, can usually be provided if the work is both necessary and possible. Without suitable people the research cannot be done. If the additional investigations now suggested are to be carried out, although the number of extra people required will not be large in relation to the number of scientists of all kinds in the country, the extra people will have to be rather specialized and of high quality. The special disciplines involved include pharmacology, toxicology, animal pathology, ecological aspects of zoology and botany, and several special aspects of chemistry, including both plant and animal biochemistry. The shortage in some of these disciplines is not confined to Britain and appears to be world-wide. It seems probable that the increased demand for people in these fields arises from the great development of the fine-chemical and related industries and the effects of this development on our environment. The education required in these fields involves more than one discipline, so that steps should be taken in both undergraduate and graduate education to provide more research workers of suitable kinds.

G. FURTHER RESEARCH NEEDS

79. Work is already being done on all the problems discussed in this report (*see* Appendices 2 and 4). The working parties have, however, indicated certain aspects on which more work seems to be urgently needed; these are listed below.

(1) *Ecological studies on whole populations of pest and other species.* Further work is needed to provide essential background information; university departments of botany and zoology might contribute to this (*see* paras. 13–15, 18). For studies on populations of wild birds, the control of an agricultural-land area of about 1000 acres may be necessary (*see* para. 18). More precise standardization of census work is needed (*see* para. 16).

(2) *Behaviour and accumulation of pesticides in soil and water and effects on soil organisms and on aquatic flora and fauna.* Intensification of research in this field is needed (*see* paras. 15 and 17).

(3) *Resistant varieties of crop plants.* More attention should be given to the possibility of breeding for resistance to important insect pests in crops where no satisfactory control is known, or where the present chemical methods are unsatisfactory (*see* paras. 22–28).

(4) *Diseases of insects.* It is doubted whether research into the exploitation of diseases of insects as a means of controlling them is adequate. There is a case for establishing an insect pathology laboratory that might in the first place concentrate on bacterial and virus diseases of insects (*see* para. 39).

(5) *Sterilants, attractants and rejectants.* The fundamental work required for the more effective use of these agents for control purposes should be supported (*see* paras. 41–46).

(6) *Effects of pesticides on birds and mammals.* Toxicological studies are needed to relate the levels found in tissues and possible toxic effects. This would supplement the information from ecological studies (*see* para. 51).

(7) *Biochemical and toxicological studies.* Support must be continued for studies on the biochemistry and toxicology of pesticides, which are fundamental to the interpretation of data obtained by analytical surveys, to the discovery of new pesticides needed to combat resistance, to the development of safer, more selective and less persistent pesticides, to the discovery of diagnostic tests of exposure to or poisoning by pesticides, and to the successful treatment of those that may be poisoned (*see* paras. 48–53).

(8) *Analytical methods.* Attention should be given to the development of quantitative methods of analysis suitable for use by Public Analysts and others. A central source of information on pesticide chemistry and analysis is required (*see* paras. 58, 62).

(9) *New pesticides.* In addition to what is being done in industrial laboratories, further effort is required on work that may lead to the development of safer, more selective, and less persistent pesticides (*see* paras. 73–74).

80. *Surveys.* The decision on the need for a monitoring service as part of the control organisation is outside our terms of reference. If it should be decided that a monitoring service is required, those concerned with research should be kept fully informed of the results (*see* para. 64).

H. PRIORITIES

81. In deciding which researches should be given priority, many factors have to be taken into account. Even then, a problem which appears to require urgent solution at one moment may soon recede in importance, because of research or other developments. It is, in fact, vitally important to keep the situation under review and to take action when needed. Of the items listed above in paragraph 79, it is apparent that high priority must be given to more extensive ecological studies and to the improvement of methods for such studies, to the assessment of the present level of contamination of the environment by pesticides, and of the toxicological significance to man and wild life. Also of high priority is the need for more research on biological control methods, particularly on diseases of insects. Of greatest importance is the need to continue and expand research which promotes the development of new pesticides to combat resistance and of safer, more selective, and less persistent pesticides.

IX. CONCLUSIONS AND RECOMMENDATIONS

82. There are no major gaps in pesticides research at the present time (Appendices 2 and 4). Nevertheless, certain aspects of research should be strengthened and to achieve this the following recommendations are put forward:—

(1) that the attention of the appropriate authorities be drawn to the need for an examination of the supply of the kinds of research workers needed for carrying out the work dealt with in this Report, with a view to action where necessary (paras. 53, 78);

(2) that the attention of all Research Councils be drawn to the need:—
  - (a) for further support for work leading to the development of more selective and safer pesticides of limited persistence (paras. 48–53, 67, 73–74, 79(7), 79(9), 81);
  - (b) for meetings to be held from time to time to correlate analytical findings (para. 60);
  - (c) for passing on information about more detailed research needs discussed in this report to appropriate research departments, including those in universities (paras. 13–15, 18, 79(1));
  - (d) for toxicological and biological studies in birds and wild life generally (paras. 51, 79(6));

(3) that the attention of the Agricultural Research Council be drawn to the need:—
  - (a) for further development of plant breeding for resistance to crop pests (paras. 22–28, 71–72, 79(3));
  - (b) for investigations into the more efficient use of pesticides including the use of attractants, rejectants, and sterilants (paras. 21, 31–47, 68, 71, 72, 73, 79(5));
  - (c) for examination of the research needs in insect pathology especially bacterial and viral diseases (paras. 39, 40, 79(4), 81);
  - (d) for continued emphasis on the importance of the integration of control methods (paras. 33–47, 71–72, 79(1), 79(4), 81 and (a) (b) (c) above);
  - (e) for further investigations with the object of understanding and overcoming the pesticide resistance developed by some strains of pests (paras. 50, 67, 73, 79(7), 81);
  - (f) for investigations of the persistence of pesticides in soils and their long-term effects on soil flora and fauna (paras. 17, 79(2));
  - (g) for machinery by which more detailed information about pesticides actually used each year in this country could be obtained and transmitted to the Research Committee and to selected research groups (paras. 19, 56, 76);
  - (h) for meetings to facilitate co-ordination between research groups (paras. 16, 36, 60, 77, 79(1));

(4) that the attention of the Medical Research Council be drawn to the need:—

   (a) for evaluation of the toxicological significance of the presence of pesticides in human body tissues (paras. 48, 52, 63, 64, 70);

   (b) for continued support and development of toxicological and biochemical studies on pesticides in mammals (paras. 48–57, 70, 75, 79(6), 79(7), 81);

   (c) for ensuring that every suspected case of pesticide poisoning in man is fully investigated and that the information obtained is made known to the Research Committee (para. 52);

(5) that the attention of the Department of Scientific and Industrial Research be drawn to the need:—

   (a) for establishing a central source of information on the chemistry and analysis of pesticides and pesticide residues (the Laboratory of the Government Chemist would seem to be the logical site for such a centre) (paras. 60, 62, 79(8), 82(2b));

   (b) for research studies on the development of analytical methods necessary and suitable for a monitoring system, if this should be considered desirable (paras. 58, 77(c), 79(8), 80);

(6) that the attention of the Nature Conservancy be drawn to the need:—

   (a) for further ecological studies on whole populations of chosen species (paras. 13–15, 18, 49, 70, 79(1), 81);

   (b) for examining the practicability of controlling a land area of 1000 acres in such a way that quantitative studies on the effects of pesticides on wild bird populations could be done (paras. 18, 79 (1));

   (c) for collaboration with certain other bodies in examining contamination of fresh waters by pesticides, in studying their accumulation in animals, and in studying the faunal and floral changes in inland waters (paras. 15, 66).

November, 1963 A. C. FRAZER (Chairman)

APPENDIX 1

MEMBERSHIP OF WORKING PARTIES

ECOLOGICAL STUDIES

*Professor O. W. Richards, F.R.S. (Chairman)	Imperial College of Science and Technology
Dr. C. G. Johnson	Rothamsted Experimental Station
Dr. D. Lack, F.R.S.	Edward Grey Institute, Oxford
*Dr. K. Mellanby, C.B.E.	Monks Wood Experimental Station, Nature Conservancy
Dr. N. W. Moore	Monks Wood Experimental Station
*Mr. W. C. Moore, C.B.E.	Harpenden
Dr. F. Raw	Rothamsted Experimental Station
Mr. H. V. Thompson	Infestation Control Laboratory, M.A.F.F.
Dr. D. L. Gunn, C.B.E. (Technical Secretary)	Agricultural Research Council

PLANT BREEDING

Dr. G. D. H. Bell (Chairman)	Director, Plant Breeding Institute, Cambridge
Dr. R. C. F. Macer	Plant Breeding Institute, Cambridge
*Mr. W. C. Moore, C.B.E.	Harpenden
Professor P. T. Thomas	Director, Welsh Plant Breeding Station, Aberystwyth
Dr. D. Rudd Jones (Technical Secretary)	Agricultural Research Council

BIOLOGICAL CONTROL AND OTHER SUBSTITUTES

*Dr. I. Thomas (Chairman)	Infestation Control Laboratory, M.A.F.F.
*Mr. D. W. Wright (Deputy Chairman)	National Vegetable Research Station
Dr. W. A. L. David	A.R.C. Unit of Insect Physiology, Cambridge
Mr. F. H. Jacob	Plant Pathology Laboratory, M.A.F.F.
Dr. C. T. Lewis	Imperial College, London
Mr. M. J. Way	Imperial College, London
Dr. D. L. Gunn, C.B.E. (Technical Secretary)	Agricultural Research Council

BIOCHEMISTRY AND TOXICOLOGY

*Professor A. C. Frazer, C.B.E. (Chairman)	University of Birmingham
*Dr. J. M. Barnes, C.B.E.	M.R.C. Toxicology Unit, Carshalton
*Dr. C. Potter	Rothamsted Experimental Station
Mr. F. P. Winteringham	Pest Infestation Laboratory, Slough
Dr. D. Rudd Jones (Technical Secretary)	Agricultural Research Council

CHEMICAL AND PHYSICAL ASPECTS

*Dr. D. T. Lewis, C.B. (Chairman)	Laboratory of the Government Chemist
*Dr. J. T. Martin (Deputy Chairman)	Agricultural and Horticultural Research Station, Long Ashton
Dr. R. de B. Ashworth	Plant Pathology Laboratory
Dr. A. H. M. Kirby	East Malling Research Station
Dr. A. H. McIntosh	Rothamsted Experimental Station
Dr. E. A. Parkin	Pest Infestation Laboratory
Dr. B. A. Southgate	Director, Water Pollution Research Laboratory
Mr. W. H. Read	Glasshouse Crops Research Institute
Dr. E. M. Thain	Tropical Products Institute
Dr. E. E. Turtle	Infestation Control Laboratory
Mr. G. A. Wheatley	National Vegetable Research Station
Dr. H. Egan (Technical Secretary)	Laboratory of the Government Chemist
Dr. D. Rudd Jones (Secretary)	Agricultural Research Council

* Member of Main Committee.

APPENDIX 2A

Some institutions where research on, or related to, ecological and population studies is in progress

FAUNA AND FLORA OF THE SOIL	
In woodlands	Universities of London (Royal Holloway College, Wye College), Manchester, Oxford (Edward Grey Institute), Southampton, Wales (Bangor); Nature Conservancy (Merlewood).
In moors, fields, gardens, etc.	Universities of Bristol, Durham, Edinburgh, Leeds, London (Bedford College, Imperial College), Wales (Bangor, Swansea); National Agricultural Advisory Service at Bangor, Cambridge, Leeds, Newcastle, Reading; Regent Street Polytechnic; North of Scotland Agricultural College, West of Scotland Agricultural College; A.R.C. Unit of Insect Physiology (Newcastle), National Vegetable Research Station (Wellesbourne), Rothamsted Experimental Station, Nature Conservancy (Merlewood).
Effects of chemicals	Universities of Keele, London (Imperial College); N.A.A.S. (Bangor); East Malling Research Station, Glasshouse Crops Research Institute, Rothamsted, West of Scotland Agricultural College; Nature Conservancy (Monks Wood).
FRESH WATERS	Universities of Durham, Liverpool, London (Bedford College, Royal Holloway College), Newcastle, Reading, Southampton, Wales (Aberystwyth, Bangor), Glasgow; Chelsea College of Science and Technology, Freshwater Biological Association, Freshwater Fisheries Laboratory (Pitlochry), Central Electricity Generating Board (R. Severn), Nature Conservancy (Monks Wood).
OTHER INSECTS	Universities of Bristol, Cambridge, Durham, Leeds, London (Bedford College, Birkbeck College, Imperial College, Queen Elizabeth College, Royal Holloway College), Manchester, Oxford (Bureau of Animal Population, Hope Department, Zoology Department), Reading, Southampton, Wales (Bangor, Cardiff, Swansea), Aberdeen, Edinburgh, Glasgow, St. Andrews; West of Scotland Agricultural College; Plant Pathology Laboratory (M.A.F.F.), Forestry Commission; A.R.C. Unit of Insect Physiology (Cambridge and Newcastle), A.R.C. Pest Infestation Laboratory (Slough), Long Ashton Research Station, East Malling Research Station, Glasshouse Crops Research Institute, National Vegetable Research Station, Rothamsted Experimental Station, Scottish Horticultural Research Institute, Nature Conservancy (Furzebrook).

BIRDS	Universities of Durham, London, (Royal Holloway College), Nottingham, Oxford (Edward Grey Institute); Infestation Control Laboratory (M.A.F.F.); British Trust for Ornithology, Eley Game Advisory Service, Game Research Association, Nature Conservancy (Aberdeen, Merlewood, Monks Wood), Wildfowl Trust.
MAMMALS	Universities of Birmingham, Cambridge, Durham, Exeter, London (Royal Holloway College, Royal Veterinary College), Reading, Southampton, Aberdeen; A.R.C. Institute for Research on Animal Diseases (Compton), Forestry Commission; Nature Conservancy (Bangor, Edinburgh, London, Rhum, Monks Wood), Infestation Control Laboratory (M.A.F.F.).

APPENDIX 2B

Institutions concerned with research on breeding plants for resistance to pests and diseases

Cereals, Field Brassica, and Herbage Crops	Plant Breeding Institute, Cambridge Welsh Plant Breeding Station Scottish Plant Breeding Station
Potatoes	Plant Breeding Institute, Cambridge Scottish Plant Breeding Station John Innes Institute
Sugar Beet	Plant Breeding Institute
Fruit	East Malling Research Station John Innes Institute Long Ashton Research Station Scottish Horticultural Research Institute
Hops	Department of Hop Research, Wye College East Malling Research Station
Glasshouse Crops	Glasshouse Crops Research Institute
Outdoor Vegetable Crops	National Vegetable Research Station Scottish Horticultural Research Institute

APPENDIX 2C

Institutions where research is in progress on pathogens, parasites, and predators, affecting insects, other land arthropods, and nematodes (eelworms), but excluding soil arthropods (see Appendix 2A).

B—bacteria; F—fungi; I—insects; M—mites; N—nematodes;
P—protozoa; V—viruses

Universities of Aberdeen (I), Leeds (B), Bristol (F), Wales (Cardiff) (I), Nottingham (I), and London (Imperial College) (P); A.R.C. Units of Insect Physiology and Virus Research (Cambridge) (V), East Malling Research Station (M, I), Glasshouse Crops Research Institute (B, N, I), National Vegetable Research Station (Wellesbourne) (I), Pest Infestation Laboratory (Slough) (B, I, M), Forestry Commission (I), N.A.A.S. (Newcastle (I.V.), Ashford (V), Reading (F)).

APPENDIX 2D

Some institutions where biochemical and toxicological studies of pesticides are in progress

BIOCHEMICAL STUDIES	
Insecticides	London School of Hygiene and Tropical Medicine Pest Infestation Laboratory Rothamsted Experimental Station
Nematicides	Imperial College of Science and Technology Department of Zoology Rothamsted Experimental Station
Fungicides	Long Ashton Research Station Rothamsted Experimental Station A.R.C. Unit of Plant Growth Substances and Systemic Fungicides, Wye
Herbicides	A.R.C. Unit of Experimental Agronomy, Oxford A.R.C. Unit, Wye Weed Research Organisation
TOXICOLOGICAL STUDIES	Medical Research Council Toxicology Research Unit St. Mary's Hospital Medical School, Biochemistry Department

(Most manufacturers have their own facilities for carrying out the necessary toxicological testing of new pesticides before they are put on the market)

APPENDIX 2E

Institutions where chemical and physical studies of pesticides and pesticide derivatives are in progress.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Laboratory of the Government Chemist
Tropical Products Institute
Water Pollution Research Laboratory

AGRICULTURAL RESEARCH COUNCIL

Ditton Laboratory
East Malling Research Station
Glasshouse Crops Research Institute
Long Ashton Research Station
National Vegetable Research Station
Pest Infestation Laboratory
Rothamsted Experimental Station
Scottish Horticultural Research Institute
Unit of Experimental Agronomy, Oxford
Unit of Plant Growth Substances and Systemic Fungicides, Wye
Weed Research Organisation

NATURE CONSERVANCY

Monks Wood Experimental Station

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Infestation Control Laboratory
Plant Pathology Laboratory

UNIVERSITY DEPARTMENT

Imperial College of Science and Technology Department of Zoology and Applied Etomology

DEPARTMENT OF TECHNICAL CO-OPERATION

Tropical Pesticides Research Unit

APPENDIX 2F

Organisations and institutions concerned with analysis or surveys of pesticide residues.

GROWING CROPS AND SOILS	East Malling Research Station
	Glasshouse Crops Research Institute
	Long Ashton Research Station
	National Vegetable Research Station
	Plant Pathology Laboratory M.A.F.F.
WILD LIFE	Infestation Control Laboratory M.A.F.F.
	Monks Wood Experimental Station
	Laboratory of the Government Chemist and other organizations (for the Nature Conservancy)
	British Trust for Ornithology
	Royal Society for the Protection of Birds
HOME-PRODUCED AND IMPORTED FOODSTUFFS	Infestation Control Laboratory M.A.F.F.
	Laboratory of the Government Chemist (for the M.A.F.F.)
HUMAN TISSUES	Shell Research Laboratories
	Laboratory of the Government Chemist (for the Ministry of Health)

APPENDIX 3

National and international bodies concerned with pesticides used in agriculture

Name of Committee or Agency	*Origin*
Advisory Committee on Poisonous Substances used in Agriculture and Food Storage	M.A.F.F.
(a) Scientific Sub-Committee of the above with the following panels:— Analytical Residues in Foodstuffs Wild Life Medical Joint panels with ABMAC and IPCA dealing with guidance on toxicity, labelling and residues	M.A.F.F.
(b) Veterinary Scientific Sub-Committee of the above	M.A.F.F.
Panel on Water Reserves and Farm Chemicals	M.A.F.F.
Carcinogenic Panel	Min. of Health
Advisory Committee of the Agricultural Chemicals Approval Scheme	M.A.F.F.
Advisory Committee on Taint	M.A.F.F.
Pesticides Analysis Advisory Committee (PAC) with panels dealing with Emulsifiability, Mercury, Lindane, Dithiocarbamates, Herbicides and Gas/Liquid Chromatography	U.K./M.A.F.F.
B.S.I. Committee on Nomenclature of Pesticides	U.K.
B.S.I. Committee (ISO/81) on Nomenclature of Pesticides	International
B.S.I. Committee on Protective Clothing	U.K.
Poisons Board	U.K.
British Weed Control Council	U.K.
British Insecticides and Fungicides Council	U.K.
Collaborative Pesticides Analytical Committee of Europe (CPAC)	International
European and Mediterranean Plant Protection Organisation (EPPO)	International
EPPO Working Party on Residues Methods	International
EPPO Standing Committee on Fumigation Standards	International
FAO Committee on Pesticides in Agriculture	International
FAO Working Party on Residues	International
FAO Working Party on Registration, Approval and Labelling	International
FAO Working Party on Resistance to Pesticides	International
WHO Expert Committee on Pesticide Residues	International
Council of Europe (Partial Agreement) Working Parties on Poisonous Substances in Agriculture and Industrial Safety and Health	
International Labour Office (Code of Practice on Safety and Health in Agriculture)	International
International Agricultural Aviation Centre, Hague	International
WHO—Specifications for Herbicides Committee	International
Association of Official Agricultural Chemists (U.S.A. and Canada)	U.S.A.
International Union for the Conservation of Nature, Toxic Chemicals Committee	International

APPENDIX 4

SUMMARY OF NEW RESEARCHES

This Summary does not give an exhaustive account of all the work in progress, but consists mainly of references to new research which has been started by the four Research Councils and the Ministry of Agriculture, Fisheries and Food to implement the recommendations of the Sanders Research Study Group Report during the past two years. It includes an account of some changes in research programmes which have taken place in the same period, and reports on certain of the more important achievements in current research. The interim Report prepared for the Minister for Science in November, 1962 (see para. 6) is incorporated in this Summary.

The research has been arranged under the Section headings in the body of the Report.

1. ECOLOGICAL STUDIES IN RELATION TO THE USE OF PESTICIDES

The most important recent development has been the completion of new laboratories for the Nature Conservancy at Monks Wood Experimental Station; these were officially opened by the Minister for Science on 28th October, 1963. An additional grant to the Conservancy has enabled five new Scientific Officers, with adequate supporting staff, to be recruited into the Toxic Chemicals and Wild Life Section.

The main lines of investigation of the Section are:—

(a) *Studies on the long-term effects of organo-chlorine insecticides on plant and animal communities*

The aim is to study the "flow" of these substances through selected ecosystems in order to discover where concentrations occur and to assess the significance of the levels of residues found.

(i) *Studies on changes in numbers and reproductive capacity on selected species*

Some of this work is being done in conjunction with other members of the Nature Conservancy's staff and with other bodies, such as the British Trust for Ornithology.

(ii) *Comparative studies of insecticide residues found in wild mammals, birds, fish, invertebrates, and plants from a wide range of habitats, throughout the country*

This work has shown that predators of vertebrates on the average contain higher residues than do herbivores and that there is extensive insecticide pollution of fresh water and marine habitats.

(iii) *Field experiments in which known amounts of insecticides are applied*

The movement of insecticides in the ecosystem is being studied and the effects recorded, such as the uptake of BHC in kale and passage to *Pieris* larvae after soil application; the uptake of DDT by worms from litter and passage to moles and other animals.

(vi) *The imbalance of natural populations due to an insecticide*

The effects of dieldrin on Heath Falsebrome (*Brachypodium pinnatum*) grassland at Blacklands Copse have been studied. Plots were sprayed in April, 1962 with a normal commercial application of dieldrin and the populations of the millipede *Glomeris marginata* were effectively destroyed. The initial effects on other millipedes, woodlice, etc. were slight. Since *Glomeris marginata* is believed to be essential in the maintenance of the *Brachypodium pinnatum* grassland, botanical changes are likely to be caused and are being carefully recorded. A check is also being maintained on dieldrin residues in the soil and vegetation, and changes in undecomposed and organic humified matter in the soils are being studied. By the end of 1962 the herbage still contained much more dieldrin than the soil, although the amount in the soil had increased. *Glomeris* was still absent from the sprayed plots but abundant in the unsprayed controls.

(v) *Toxicological studies to discover the significance of residues found in wild populations*

These will be started in 1964. Particular attention will be paid to the possible occurrences of sub-lethal effects on reproduction and behaviour.

(b) *Ad hoc field trials on the effects of new pesticides on birds*

Studies in conjunction with M.A.F.F. and the firms concerned have been made on Dinoseb (a potato-haulm killer) and Phorate granules (an insecticide).

(c) *Studies on the long-term effects of herbicides*

Experiments are being done on the effects of repeated application of MCPA on soil animal communities in a chalk soil. A study is being made of selective effects of different herbicides on populations of polyploid species.

Anatomical and physiological studies of sublethal effects of herbicides are also in progress. Experiments have been made with 2, 4-D and 2, 4, 5-T on Hawthorn at High Halstow National Nature Reserve and on Alder Buckthorn (*Frangula alnus*) at Wicken Fen. Preliminary results suggest that a mixture of these substances when applied to cut stumps causes no undesirable effect to neighbouring plants or soil fauna.

(d) *Herbicides used for the control of freshwater weeds*

At the suggestion of Plant Protection Ltd., the Section is making use of the Company's trials on the effects of diquat and paraquat on submerged water weeds. Much experience has been gained with the problems of recording aquatic vegetation and invertebrate populations and in assessing the results. These substances do not appear to cause serious direct poisoning but they radically alter the habitat.

A Scientific Officer has been appointed to the A.R.C. Weed Research Organisation to carry out an ecological survey of aquatic weeds and present control methods.

(e) *Background studies of farmland habitat*

These studies include: general surveys on abundance of hedge types; a study of the insect fauna of hawthorn hedges; a study of the relation of bird species to types of hedge management; and an investigation of the spread of weeds from hedges into surrounding land.

BIRD AND MAMMAL PESTS

Studies on bird and mammal pests, including wood pigeons, bullfinches, carrion crows, rabbits, squirrels, moles, rats, mice, and coypus, are undertaken by the Infestation Control Laboratory of the M.A.F.F. The A.R.C. has recently made a grant to the Department of Natural History, Aberdeen University, for research on the ecology, behaviour, and economic status of the rook.

INSECT PESTS

At Rothamsted the appointment of an additional Scientific Assistant has been approved, to help in the initiation of a continuing census of insect pests with a view to the prediction of population changes.

EFFECTS OF PESTICIDES ON WILD LIFE

Since 1959, the M.A.F.F. Infestation Control Laboratory has been investigating incidents of deaths of birds suspected of being associated with the use of cereal-seed dressings containing organo-chlorine insecticides. Experiments are in progress to determine the levels of residues likely to cause death in different species. This work, together with observations made by the Royal Society for the Protection of Birds and the British Trust for Ornithology, led in 1961 to a voluntary ban on the use of aldrin, dieldrin, and heptachlor on spring-sown cereals and a restriction on their use on autumn-sown cereals to crops where there was a real danger of attack by wheat-bulb fly. Survey and experimental work has continued each year since. The voluntary ban has been well observed and there have been very few incidents for which these toxic chemicals were responsible. In 1962 and 1963 the scope of the enquiries was widened to include all incidents of deaths of birds reported to the Department. DDT and gamma-BHC were found on a few occasions in small amounts and there were very few confirmations of deaths of birds from causes other than seed dressings. In a few instances, however, substantial residues of dieldrin were found, especially in predatory birds.

EFFECTS OF PESTICIDES ON BEES

For some years work has been in progress at Rothamsted on biological, chemical and biochemical methods for the detection of micro-quantities of poisons in bees. Earlier work was concerned chiefly with methods of micro-bioassay; more recently studies have been made on techniques for detection of organo-phosphorus poisoning by cholinesterase determinations on dead bees and during the last few months work on chemical methods of detection using the gas/liquid chromatograph has been started.

The methods developed have been used to help the Bee Advisory Service of the M.A.F.F. by identification of the causes of death of bees sent to the Ministry as suspected of being poisoned with pesticides.

Laboratory and field methods for the assessment of toxicity to bees have been worked on in the past but are not entirely satisfactory, particularly field methods. An additional Scientific Officer has been approved to work on the toxicity of pesticides to bees and other pollinating insects.

EFFECTS OF PESTICIDES ON AQUATIC LARVAE AND FISH

The Water Pollution Research Laboratory has carried out pilot scale studies initiated in 1960 of the control of chironomid larvae in ponds using DDD absorbed on an inert base.

The Laboratory of the Government Chemist analysed for DDD samples of effluent from a pond and of bottom mud, taken at intervals up to 10 months after spraying had taken place. Results showed that although the concentration of pesticide in the water rapidly fell to a negligible value, half the initial DDD concentration in the mud was still present 4 months after spraying and about 15 per cent after 10 months.

The possible toxic effluent of the insecticide spraying on fish was studied using mirror carp. Results obtained were, however, inconclusive. DDD concentrations in carp killed in November 1962 varied between 9 and 15 p.p.m.

POSSIBLE CONTAMINATION OF WATER SUPPLIES BY PESTICIDES

In response to a request by the Interdepartmental Panel on Water Reserves and Farm Chemicals which was appointed by the Minister of Agriculture, Fisheries and Food, and on which the M.A.F.F., Ministry of Housing and Local Government, and the Department of Scientific and Industrial Research are represented, the National Agricultural Advisory Service of M.A.F.F. is carrying out a series of experiments on the percolation of water containing a pesticide through various soil samples. The analysis of the percolates is being undertaken by the Laboratory of the Government Chemist. It is understood that, when the results of these studies are known, the need for further work will be considered and the Water Pollution Research Laboratory will participate, as appropriate, in any such studies.

The Water Research Association decided to investigate the possible contamination of water supplies with pesticides and herbicides in 1962, not only because of possible health hazards, but also because very small concentrations of these substances or their degradation products might lead to serious taste and odour problems. It was recognized also that there was a particularly serious aspect to the situation in cases where pollution of this kind might be affecting waters charging underground aquifiers, in view of the long-term persistence of the effect resulting from the slowness of the transport through the porous strata. The Association intends to develop suitable techniques for the detection and determination of pesticides in water, and work has been started with a survey of the literature. Useful information has been obtained from organizations having experience in related fields and the manufacturers of agricultural chemicals have been approached for their co-operation.

2. SUBSTITUTES FOR CONTROL OF PESTS BY PESTICIDES ALONE

RESISTANT VARIETIES OF CROP PLANTS

Work is continuing in this field at the various plant breeding institutes. An additional plant breeder has been appointed to the Plant Breeding Institute, Cambridge, on funds provided by the Sugar Beet Research and Education Committee, to increase research on the development of sugar beet varieties resistant or tolerant to virus yellows disease. If this breeding work is successful it could greatly reduce the use of insecticides for the control of the aphid vectors of this disease.

Breeding of barley for resistance to powdery mildew (*Erysiphe graminis*), using diverse sources of resistance, is being conducted at both Aberystwyth and Cambridge and the first resistant variety from Cambridge was marketed in 1963.

BIOLOGICAL CONTROL AND INTEGRATED CONTROL

At the National Vegetable Research Station an additional Assistant Experimental Officer has been appointed to intensify the work on the predation of cabbage-root-fly larvae by ground beetles. Experiments have been carried out which show that residues of 0·65 lb per acre of dieldrin or aldrin can reduce the numbers of the most useful species of predators by up to 20%, and consequently can increase appreciably the damage to the crop caused by the pest.

The A.R.C. is supporting research in the Hope Department of Zoology, University of Oxford, on the life histories and host relationships of the *Encyrtidae* group of *Chalcidoid Hymenoptera*. This is a group of parasitic wasps about which little is known although it is of considerable potential usefulness for the control of psyllid plant-sucking bugs.

Further research on the integration of biological and chemical methods of control has recently been started. The A.R.C. has made a grant to the Department of Zoology and Applied Entomology, Imperial College, London, for research on the population-biology of aphids in relation to the importance of natural enemies in their control, and the best ways of applying chemical control measures so as to interfere as little as possible with natural control.

Research has been in progress at East Malling Research Station for more than ten years on the natural control of orchard pests and especially on the effects of different spray programmes on the fruit-tree red-spider mite and its predators. Recently lead arsenate has been found to be the only insecticide which gives any control of codling moth without destroying its predators. It is possible to improve the performance of lead arsenate by an additional large-volume application at petal fall.

OTHER METHODS OF CONTROL

Diseases of insects

Increasing interest is developing in this country in the use of bacterial parasites of insects, especially *Bacillus thuringiensis*. The use of this organism for the control of pests of stored products is being studied at the Pest Infestation Laboratory, and at Rothamsted it has been used in experiments on the control of wax moths (*Galleria mellonella*) in beehives.

The Agricultural Research Council has made a grant to the Bacteriology Department, Glasgow University, to support a study of aerobic spore-forming bacteria pathogenic for Lepidoptera. A similar grant has been made to the Department of Agriculture, Leeds University, for a study of factors affecting the efficiency of crystalliferous bacterial pathogens in insects.

Work is in progress at Cambridge in the A.R.C. Units of Insect Physiology and Virus Research on the use of granulosis viruses to control insect pests.

The Department of Technical Co-operation has made grants to the Botany Department, Bristol University, for research on fungal pathogens of insects; to the Department of Zoology and Applied Entomology, Imperial College, London, for work on protozoan parasites of insects; and to the Department of Forestry, Oxford University, for research on fungal and viral parasites of insect pests of forest trees.

Attractants, repellents and rejectants

Workers at Long Ashton Research Station have been attempting to find a specific repellent which may be used to discourage attacks on fruit buds by bullfinches, which is a problem of increasing concern to fruit growers. So far this research has met with limited success.

The A.R.C. has provided financial support for Dr. C. J. Duncan, Zoology Department, Liverpool University, to investigate the taste-reactions of birds and the use of repellents. When presented in water, β-naphtol was repellant to pigeons but substances added to food were much less effective, choice of food appearing to depend more on size and shape of grains.

In experimental work by the M.A.F.F. Infestation Control Laboratory at Carlton, Cambridgeshire, over a period of three years considerable success has been achieved in catching wood-pigeons by the use on clover leys of baits treated with 1·5% alpha-chloralose (glucochloral). Used as a method of control the experiments at first showed that there was considerable risk to protected species and game birds. The risk to the former has been largely eliminated by using large-sized bait such as maple peas and beans, but the risk to game birds remains. There is no risk to human beings and practically none to predators.

The Tropical Products Institute is at present engaged on a study of sex attractants for the control of certain tropical insect pests and pests of stored products.

3. BIOCHEMICAL AND TOXICOLOGICAL STUDIES

MODE OF ACTION AND DETOXICATION STUDIES

Work has been completed at Rothamsted, in collaboration with the Tropical Products Institute, on the separation and reconstitution of the four known active principles of pyrethrum and on their selective biological effectiveness to house flies, alone and in combination with piperonyl butoxide. This, together with synthetic work on pyrethrins and related compounds, has yielded valuable information on the mode of action of these chemicals, which have a low mammalian toxicity, and on the use of synergists to increase toxicity to insects.

Similar studies on the mode of action of organo-phosphorus insecticides at Rothamsted and organo-chlorine insecticides at the Pest Infestation Laboratory may be expected to give a lead in the development of new, less toxic and more selective insecticides. Research has been started at P.I.L. on wasp venoms which are highly toxic to some insect species yet apparently innocuous to other animals. One of these, *Microbracon* venom, is being studied in the hope of its ultimate exploitation or simulation in a synthetic insecticide.

At the A.R.C. Unit of Insect Physiology, research is in progress on various aspects of the physiology of the insect nervous system in an attempt to elucidate some of the fundamental factors involved in mechanisms of insecticidal poisoning. In particular, attention has been paid to the processes involved in the exchange of ions and molecules between the blood and nervous tissues.

At the A.R.C. Unit of Plant Growth Substances and Systemic Fungicides, Wye College, studies are directed at determining the relationship between chemical structure and biological activity in auxins and fungicides.

The A.R.C. has made a grant to the Department of Biochemistry, St. Mary's Hospital Medical School for work on the oxidative detoxication of foreign organic compounds in insects, mites, ticks and spiders, including insects of agricultural importance. The initial work will be carried out with non-toxic compounds related to insecticides, but will eventually be extended to include some insecticides.

STUDIES ON RESISTANCE TO INSECTICIDES

Research has been intensified at Rothamsted on the mechanism of resistance to organo-phosphorus insecticides, and the appointment of an additional Scientific Officer has been approved to develop the use of histochemical methods in this work. A histochemist has been appointed also to the staff of the Pest Infestation Laboratory to work on mode of action and resistance, and consideration is being given to starting an investigation of the genetic basis of resistance to contact insecticides, which is an increasing problem with stored products pests. Similar work on resistance in house flies has been in progress at Rothamsted for several years.

In the Biochemistry Department of the Pest Infestation Laboratory, work on resistance together with the world-wide survey conducted on behalf of the World Health Organisation has strongly indicated that the only practical solution for dealing with resistant insect populations in the field is to turn to a new insecticide or to a new method of control. Therefore, the emphasis of research has been shifted from studies of the resistance mechanism itself to those more directly related to the ultimate development of new insecticides. Recent work in the Department and in other laboratories suggests important potentialities in the development of synergists or detoxication inhibitors. The effectiveness of carbamates, for example, against insects which have become resistant may be largely restored by the use of methylene dioxyphenyl synergists so that virtually a new insecticide becomes available. It is also known that the selective action of some existing insecticides e.g. malathion, is due to relatively greater rates of detoxication in the mammal than in the insect. Comparatively little is known of the enzymic mechanisms involved and their inhibition. Studies are about to be undertaken, therefore, on the enzymic mechanisms of synergistic action.

There has been little indication, so far, of significant resistance to pyrethrum being developed in the field by various insect pests. However, it has been found at the London School of Hygiene and Tropical Medicine that in one strain of house flies, *Musca domestica*, a resistance has developed towards both DDT and pyrethrum. In order to study this matter further, pyrethrin I has been synthesized by the Tropical Products Institute incorporating ^{14}C in the cyclopropane ring, and the material has been used in a collaboration between the two laboratories to study the cause of this resistance. It has been found that at least a part of the resistance can be attributed to a slower penetration of the pyrethrin through the insect cuticle of the resistant strain compared with the susceptible strain.

Entomologists at the National Vegetable Research Station have recently discovered a strain of cabbage-root fly infesting sprouts that is resistant to dieldrin, and an alternative insecticide for the control of this pest is the organo-phosphorous compound diazinon. Resistance to warfarin in populations of farm rats, particularly in Shropshire, has been reported also and is being investigated by the M.A.F.F. Infestation Control Laboratory. In this work, the Laboratory is in close liaison with the M.R.C. Blood Coagulation Unit at Oxford and the Genetics Department, Liverpool University.

TOXICOLOGICAL STUDIES

Work is continuing at the M.R.C. Toxicology Research Unit on some of the basic aspects of toxicology. Certain organo-phosphorus compounds, including some used as pesticides, can produce a delayed neurotoxic injury in man and some species of animals. Attempts to discover the biochemical disturbances associated with these lesions are in progress.

The mammalian toxicities of 28 insecticides have been determined and in a number of instances the effects of repeated dermal or oral dosing, the effects on blood and brain cholinesterase, and the therapeutic action of oximes have also been assessed. The majority of compounds studied have been organo-phosphorus compounds or carbamates which may possibly be suitable for use in vector-control programmes. The object of the work is to form a basis for assessing the hazards to men applying these materials in vector-control work.

Biochemical studies of a more fundamental nature on the effects of organo-tin fungicides on the metabolism of mammalian brain *in vitro* and *in vivo* are in progress. The problem of striking differences in the sensitivity of some species to triphenyltin acetate is being investigated with the aid of a "labelled" tin salt.

The possible value of behaviour tests in detecting early toxic effects from alkyl mercury compounds and trialkyl tin compounds is being examined.

Research workers at the Tropical Products Institute have been making a study, for the World Health Organization, of the metabolites of some carbamate insecticides excreted in human urine. This investigation is associated with a technique for finding out how much insecticide has been absorbed by, for example, a spray operator. It was found that the excretion of normal dietary phenols is temporarily suppressed after taking either carbamate insecticide or 2-isopropoxyphenol (a metabolite of carbamate insecticide).

The findings on the rate of excretion and percentage of recovery of this phenol, together with the observations on the depression of excretion of normal phenols, are useful in determining the limits of applicability of a simple colorimetric method for the determination of total urinary phenols unsubstituted in the para position, which has been studied by the M.R.C. Toxicology Unit.

The British Industrial Biological Research Association was set up in 1960 to undertake research into the methods of testing food additives, both intentional and adventitious alike, to ensure that such additives are harmless to those consuming the foods. The programme of basic research, part of which is already under way, is aimed at providing toxicological information which will be generally applicable to substances in all the fields involved. Research is in progress on more sensitive methods of detecting interference with biological processes by substances having low toxic potential; and in particular on the assessment of early and delicate adverse effects exercized on the liver by such substances.

This Research Association plans to move in mid-1964 to its own Laboratories on the M.R.C. site at Carshalton, Surrey, and the volume of effort specifically devoted to pesticide residues on the future programme will inevitably be related to the degree of financial support for this work.

The M.A.F.F. Infestation Control Laboratory has done experimental work on the toxicity of organo-chlorine insecticides to birds and is co-operating with the Game Research Association in studies of the effects of these chemicals on the fertility of game birds.

FIELD HAZARDS

The application of the more toxic chemicals in the field can lead to hazards both to the user and to third parties. There is now a small unit at the M.A.F.F. Plant Pathology Laboratory, equipped with a mobile laboratory, whose task it is to go into the field and pin point where the hazard lies in using the more toxic chemicals.

A beginning has been made by determining the concentration of dimefox (the most volatile and one of the most poisonous of the organo-phosphorus chemicals in use) in the air, in the vicinity of a spray tanker being filled, and in a hop garden during, and after, application. Results indicate that not more than 0·2 mg/m^3 of dimefox may be expected in the atmosphere when diluting the concentrate. Similar work has been carried out with the fungicide, bis-ethylmercury phosphate.

Investigations are proceeding on hazards likely to arise from the use of granular insecticides.

4. CHEMICAL AND PHYSICAL ASPECTS

ANALYTICAL METHODS

The Laboratory of the Government Chemist maintains a Pesticide Residues Research Unit, whose work is largely concerned with the development of new and improved methods of analysis for pesticide residues in plants, animals, water, and soil.

Recent developments include the improvement of clean-up processes for fatty tissues using dimethylformamide; the extension of the range of usefulness of the very sensitive gas-chromatographic method of residue analysis to further pesticides, including a number of organo-phosphorous compounds; the improvement of paper-chromatographic methods for chlorophenoxyacid and other herbicide residues; and the use of thin-layer chromatography for both organo-chlorine and organo-phosphorus residues. The use of infra-red spectroscopy at low residue levels has been found possible for certain systems.

Many of the A.R.C. institutes are concerned with the development of new and more precise methods of analysis for pesticides of special interest, and additional assistance has been provided to help speed up this work.

In order to overcome the difficulties associated with the variability of analytical results at different centres, the M.A.F.F. Plant Pathology Laboratory has been examining methods of analysis available, for the more important chemicals and crops, by carrying out collaborative analytical work on them, in conjunction with other laboratories. In this way methods are evolved which are capable of giving reproducible results in different laboratories. The Laboratory is responsible also for collaborating with F.A.O. and the European Plant Protection Organisation (EPPO) in the development of standard analytical methods which are internationally acceptable.

The Tropical Products Institute is concerned with the development of analytical methods for the estimation of naturally occurring pesticides, in particular, lonchocarpus, derris and pyrethrum. The Institute is represented on a joint Pharmaceutical Society/Society for Analytical Chemistry panel formed to investigate methods of assay of pyrethrum. The Institute has recently developed methods of gas/liquid chromatography capable of detecting very small amounts of some organo-phosphorus insecticides and of pyrethrum; the pyrethrum method has been used for the detection and determination of residues in animal tissue. The Institute also advises the World Health Organization on pesticides, their specification and formulation, and on appropriate methods of analysis.

SURVEYS OF PESTICIDE RESIDUES

The Scientific Sub-Committee of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage set up a Residues Panel to undertake selective surveys, as recommended by the Sanders Research Study Group. A number of preliminary surveys have been completed, including, both home-produced and imported butter, milk, imported beef fat and corned beef, for organo-chlorine residues; and imported apples for lead, arsenic, and parathion. Further surveys on these commodities and on home-produced and imported mutton fat and home-produced beef fat are in progress. The analyses for these surveys have been carried out by the Laboratory of the Government Chemist.

The M.A.F.F. Plant Pathology Laboratory has, in conjunction with the Veterinary Laboratory, determined the residues of mercury occurring in the flesh and eggs of hens after feeding them on dressed grain. It has been shown that about 8 p.p.m. of mercury will be found in eggs if hens are fed a ration including grain treated with a proprietary liquid mercury seed dressing. Subsequent work has shown that sufficient of the fungicide cannot be washed off surplus treated grain so as to make it safe to feed to livestock.

The determination of mercury in potatoes, whose tops have been sprayed with a mercury fungicide to control potato blight, has been carried out over three seasons at the Plant Pathology Laboratory. No hazards are considered likely to arise from this practice.

Preliminary work on the following surveys of residues in commercially-grown crops is being undertaken at the Laboratory:—

1. Dimethoate residues in certain vegetable and fruit crops.
2. Demeton-methyl residues in certain vegetables and fruit crops.
3. Dieldrin and aldrin in carrots and potatoes grown in soils known to have been treated with dieldrin and aldrin.

Long Ashton Research Station has recently completed an exhaustive study of the up-take and movement of mercury in apple leaves and fruit, following commercial applications of an organo-mercury fungicide. This has shown that the mercury deposits fall to low levels between successive applications and, at harvest time, the mercury on the fruits is normally less than 0·1 p.p.m., although this is dependent on the efficiency of application. Part of the mercury in the fruit appears to have been translocated from the leaves, and mercury has also been detected in potato tubers where the leaves have been treated with a mercury fungicide. There is apparently no up-take of mercury by root crops (e.g. turnip) from soil treated with mercury compounds for club-root control.

Similar studies have been carried out by East Malling Research Station on residues of endrin in blackcurrant fruits at harvest which have been treated for the control of big-bud mite, and on aldrin and dieldrin residues in strawberry fruits being treated for the control of strawberry-seed beetle. The M.A.F.F. Plant Pathology Laboratory has been looking at residues of triphenyl tin, a new fungicide for the control of potato blight, on potato leaves and tubers, and has found that there are residues of 10–12 p.p.m. on the leaves two weeks after application, but there are no detectable residues in the tubers at this time.

The Nature Conservancy has been determining residues of organo-chlorine insecticides in birds. To discover the background contamination in a much-sprayed area, a relatively unbiased sample was obtained by analysing specimens killed by motor traffic. Results so far show that about one third of the total population contains more than 0·1 p.p.m. of residues of organo-chlorine compounds. Residues have been determined also in avian and mammalian predators and their prey. Wherever possible the analyses, which are carried out by the Government Chemist's Laboratory, are made from muscle, liver, brain and fat samples. Detectable residues have already been found in a fox, a stoat, a heron, two owls and a great crested grebe.

Analysis of eggs of predatory birds are also being made. Residues have been found in the addled eggs of a peregrine falcon (115 μg. of DDE, 50 μg. dieldrin, 28 μg. heptachlor epoxide and a trace of gamma BHC and heptachlor) and a Montagu's harrier (5 p.p.m. DDE and a trace of dieldrin).

PESTICIDE RESIDUES IN THE SOIL

The National Vegetable Research Station, in collaboration with the M.A.F.F. Plant Pathology Laboratory, has made a study of residues of aldrin, dieldrin, DDT and BHC in 21 farm fields. DDT appears to be the most commonly distributed insecticide in arable soils at the present time, but BHC has been detected causing taint in potatoes 15 years after the last application. Other work at the N.V.R.S. has shown that the half-life of dieldrin residues in soils is from 4 to 7 years.

A scientific assistant has been appointed to assist in the provision of a routine service for the paper-chromatographic analysis which is used in this work.

A Scientific Officer has been appointed to the Weed Research Organization to develop methods for studying the persistance of herbicides in the soil.

The A.R.C. is supporting a study of the long-term effects of nematicides on a variety of organisms in the soil as well as on crop plants, to be carried out by the Department of Zoology and Applied Entomology of the Imperial College of Science and Technology, London, at the College Field Station.

NEW PESTICIDES

An example of the development of less persistent pesticides is provided by diazinon which has been found by workers at the National Vegetable Research Station to be an effective alternative to dieldrin for the control of carrot-root fly. Another example is paraquat, a general-purpose weed killer which is inactivated very rapidly on contact with soil.

A new group of compounds derived from 4-hydroxybenzonitrile has been synthesized at the Department of Physical Sciences, Wye College; these have been shown to have useful herbicidal and molluscicidal properties.

APPLICATION OF PESTICIDES

At Long Ashton Research Station research has been going on for several years into the chemical nature of the plant cuticle with reference to retention and absorption of chemicals and to the effect of formulation on penetration. This work is now being intensified.

The A.R.C. has made a grant to the Department of Textile Industries, Leeds University for research on the constitution of insect and plant waxes, and this may be expected to yield useful information on the same problems.

An A.R.C. Technical Committee on Research on Spray Drift was set up in 1961 to co-ordinate research being carried out into damage from spray drift, and to consider whether additional research was needed. The number of cases of damage continues to fall and this is apparently due to a greater awareness on the part of contractors and farmers of the possible consequences of spray drift.

Researches on damage by spray drift to vegetable crops at the National Vegetable Research Station, and on damage to tomatoes at the Department of Horticulture, University of Nottingham, have now been completed and the results published. Sets of colour slides illustrating the symptoms of damage have been made available to the N.A.A.S. for the diagnosis of cases of suspected damage by spray drift.

AGRICULTURAL RESEARCH COUNCIL

Report
of the
Research Committee
on
Toxic Chemicals

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